ASSESSMENT OF GEOTECHNICAL PROPERTIES OF SOILS IN AHOADA, NIGER DELTA, NIGERIA

Uzoegbu, M. U.

Department of Geology, College of Physical and Applied Sciences, Michael Okpara University of Agriculture, Umudike, PMB 7267, Umuahia, Abia State.

GSM: 08030715958; Email: mu.uzoegbu@mouau.edu.ng

ABSTRACT

This study investigates the geotechnical index properties of soil used in the construction of Road at Ahoada, Niger Delta Region. The work was carried out by assessing the suitability of the soil as a sub-grade material. The test carried out includes; Atterberg limit, particle size distribution, compaction and California bearing ratio. The range of value obtained for liquid limit was 37.0% - 39.7%, 21.3% - 25.2% for plastic limit, 14.5% -15.9% for the plasticity index. The range of values for the maximum dry density is 1.87 – 1.94%, for the optimum moisture content is 14.0 – 14.5%. The percentage that passed sieve number 200 ranges from 22.5 – 25.5%. The California bearing ratio ranges from 13 - 24% while the value from American Association of High way officials (AASHO) classification, classifies the soil as an A-2-7 Sub-grade material. These results indicates that the soil meets the specifications for soil to be used as a sub-grade material with respect to laid down guidelines by the Federal Government of Nigeria.

Key words: Soil, Geotechnical properties, Liquid and Plastic limits, Particle size, density, Road, Ahoada, Niger Delta.

Introduction

Ahoada is located northwest of Port Harcourt, Rivers State (Fig. 1) at latitude 5° 03ʹ 0″ to 5° 07ʹ 0″ N and longitude 6° 39ʹ 0″ to 6° 41ʹ 0″ E

Geotechnical assessment is important in civil engineering, but also has applications in other disciplines that are concerned with construction on both ground and underground surfaces.

There is indeed a national and global recognition of the fact that it is imperative that the geotechnical index properties of soils used for engineering constructions are determined before they are used for any construction work in order to avoid early failure of the structure and also waste of time, resources and most of all, lost of lives, since the roads and structures are going to be used by vehicles as well as pedestals on daily basis.

In view of this, many works and standards have been laid down as guide by authors, due to the fact that the construction of road depends to a large extent on the properties of road materials such as durability, strength, stiffness, permeability and volume stability (Akpokodje, 2001).

Also the American Association of the State Highway Officials (AASHO) adopted the system developed by the bureau of public roads after extensive revision in 1966 and used it for the evaluation of quality of soil for road construction, the British Standard (BS) code 1377 of 1990 and unfired soil classification scheme. All these bodies laid down standards

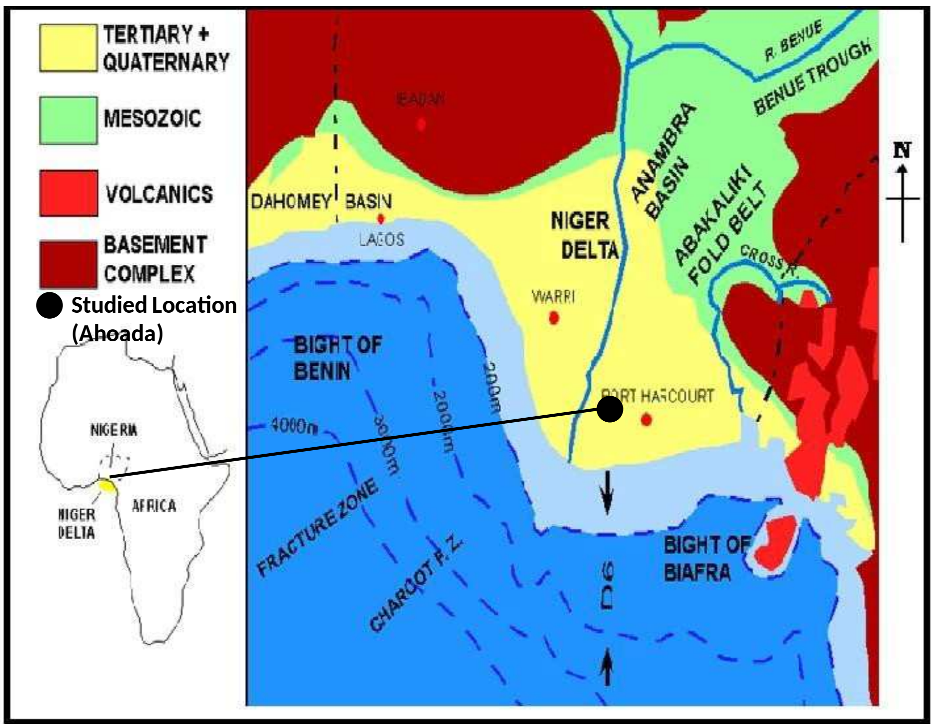

Fig. 1: Map showing the studied area (in set; map of Africa showing location of Nigeria).

as guide in engineering construction in order to avoid failure of engineering structures. This paper deals with the analyzing the geotechnical index property of soil and suitability used in the construction of Road at Ahoada, Niger Delta region.

REGIONAL GEOLOGIC SETTING

Ahoada lies within the Niger Delta basin which began formation in the Eocene time and has continued to recent. Etu-Efeotor, 1997 and Short and Stauble, 1967 recognized three subsurface stratigraphic unit in the Niger Delta. These include the Akata Formation, the parallic Agbada and transitional Benin formations (Table 1).

Akata Formation is a primary source rock for Niger Delta, the most prolific petroleum system in Africa. It is the oldest of the three litho-stratigraphic units of the Niger Delta and made up of old shales which range in colour from dark to grey and consist of plant remains at the top. Anyanwu et al. (2003) proposes that the Akata Formation is the only source rock volumetrically significant and whose depth of burials is consistent with the depth of the oil window.

Table 1: Lithostratigraphic Section of the Niger Delta (After Etu-Efeotor, 1997 and Short and Stauble, 1967).

Geologic unit	**Lithography**	**Age**
Alluvial, fresh water, brackish swamp, meander belts	Sand, clay, silt and some gravel	Quaternary
Mangrove and silt water/ brackish swamp	Medium-fine grain sand, clay and silt	Quaternary (recent deposits)
Active/abandoned beach ridges	Sand, clay and silt	
Sombrero-warri Deltaic plain	Sand, Clay and silt	
Benin formation	Poorly stored medium coarse grained sand, clay and silt	Miocene
Agbada formation	Clay lenses and sand	Eocene
Akata formation	Clay, silt and shale	Paleocene

Allen (1965) used maturation models to conclude that both Akata and Agbada shales sources the oil. Doust and Omatsola (1990) concluded that the source organic matter is in the deltaic offlap sequences and in the sediments of the lower coastal plain and their hypothesis implies that both the Agbada and Akata likely have disseminated source rock levels. This formation ranges in age, from Paleocene to Holecene and is over pressured (Etu-Efeotor, 1997).

The Agbada Formation underlies the Benin Formation and forms the second of the three strongly diachronous Niger delta complex formations. The formation is made up of alternating succession fine sand, silt and shale. The sand particles are coarse rich in micro fauna at the base. This formation presents thickness of about 1,22m (Etu-Efeotor, 1997). This formation is believed to be the reservoir rock for petroleum in the Niger Delta. Its age ranges from Eocene to the recent and about 99% of sandstone reservoir rock in the Niger Delta that occurs within the succession (Amajor, 1991).

The Benin Formation extends from the west across the whole of Niger Delta coastline. It is over 99% sand with intercalation of shales (Etu-Efeotor, 1997). The sands are gravelly, coarse – fine grained formed during the Miocene. The Benin Formation is also described as “coastal palm sand” which outcrops in Benin, Onitisha and Owerri Provence and elsewhere in the Delta area.

Etu-Efeotor and Odigi (1983) subdivided the Niger Delta to three main hydrological zones, namely;

i. Coastal zones of deep aquifer which consists of sand bar beaches.
ii. A transition zone of marines and continental deposits
iii. A Northern zone of shallow aquifer of about 60meter, which consist of continental deposits.

This zone is prominent in the upland area around Ahoada.

The principle source of ground water within the Niger Delta is the infiltration of rain water. The ground condition is fairly complex because of the numerous perched aquifers besides the normal ground water aquifers.

The quality of ground water in the area is characterized by the occurrence of variable quantities of iron and salt water intrusion (Okoronkwo and Odeyemi, 1985). O’flaherty (2001), examined the composition of water borehole and the composition of groundwater after a due consideration of some cat ions and anions in the water, and reported that most iron in Niger Delta were from supergene enrichment process. He also affirmed that the common source of magnesium in the Niger Delta is the weathering of biotte and dolorite. All these create engineering geological implications within the associated rocks and soils.

There use to be a high recharge during raining season which causes an increase in hydrostatic pressure causing the soil not be well drained. This increase in hydrostatic pressure can induce liquefaction tendencies of these soils creating geotechnical problems during the raining season. The water table increases due to recharge and this in turn, results in increased groundwater flow rate.

MATERIALS AND METHODS

The burrow pit has been the source of the material used in the sub-grade layer of the construction especially roads. The samples were collected from three different burrow pits at depth of 3 meters respectively. The samples were labeled as shown below in Table 2.

Table 2: Indicating the sample source and codes.

Source of Material	Sample Codes	Depth (m)	Description
Borrow Pit (Trail Pit 1)	Tpt 1	3	Silty sand of fine texture
Borrow Pit (Trail Pit 2)	Tpt 2	3	Silty sand of fine texture
Borrow Pit (Trail Pit 3)	Tp 3	3	Silty sand of fine texture

Laboratory analysis were carried out on the disturbed soil samples collected from the field in other to determine the geotechnical index properties. These were done in the Engineering Laboratory of Setraco Nigeria limited Company.

The analysis carried out on the disturbed samples include

- Liquid limit, plastic limit (Atterberg limit)
- Compaction test
- Sieve analysis (Grading)
- California bearing ratio.

According to Atterberg, 1911, a Swedish agricultural scientist who engaged in agriculture and ceramic proposed four states of soil consistency based on water content and stated that the liquid limit of a soil is the moisture content at which the soil passes from plastic state to liquid state as determined by the liquid limit test.

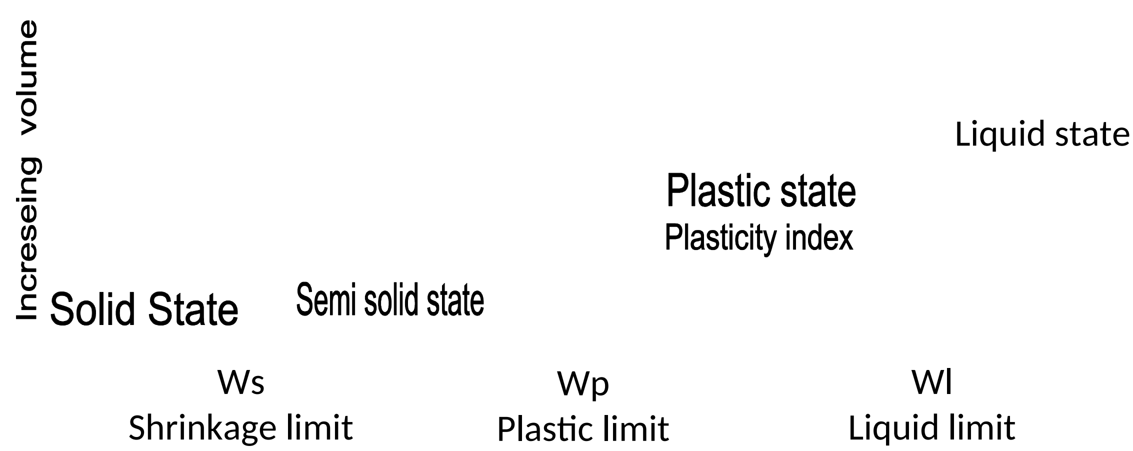

Fig. 3: Atterberg limit and related indices (After Akpokodje, 2001).

Particle size distribution refers to the percentage of the various grain sizes present in a rock as determined by sieving or sedimentation. It is one of the geotechnical index properties used to classify a soil based on size.

Soil engineers have established defined limit for the difference particle size found within a soil. The amount of particle size present is determined by mechanical analysis. Particles size distribution yield information on the size group of a sample's solid particles and relative proportion of the sizes, and this is a very important property which influences the engineering behavior of soil.

RESULTS AND DISCUSSION

The results of the laboratory tests carried out during these studies are presented below. A summary of the liquid and plastic limit results are shown in Table 3

Table 3: Summary of Atterberg Limit.

Source	**Depth**	**Liquid Limit (%)**	**Plastic Limit**	**Plasticity Index**
Trail Pit 1	3 m	38.6	22.7	15.9
Trail Pit 2	3 m	37.0	21.3	15.7
Trail Pit 3	3 m	39.7	25.2	14.5
Range		37.0 – 39.7	21.3 - 25.2	14.5 - 15.9
Specification		< or = 50%		< or = 30%

Table 3 shows the range of the Liquid limit and Plasticity Index of the three trail pit, and the standard specification given. Ramamurthy and Sitharam (2005) gave the Atterberg limit of soils in the Niger-Delta generally moderate as (LL 39 - 86%; PL 24 - 62%) with values increasing with increasing fines. Also Akpokodje (2003) in his work, Geotechnical index properties of pavement soil material from Aluu, Rivers State gave the liquid limit value generally moderate to high 41-53%, the plastic limit as moderate to high range from 21%-39% concluding that the soil did not meet up the standard specification of acceptable base course material and therefore requires cement stabilization.

The results from Table 3 shows the liquid limit ranges from 37.0-39.7%; Plastic Limit 21.3 - 25.2 and Plasticity Index ranges from 14.5 - 15.9, the soil meets up the standard specification given by the Federal Government of Nigeria, hence classifying the soil as generally moderate and suitable for sub-grade material.

A summary of the result derived from the compaction test carried out is shown on Table 4.

Table 4: Summary of Standard ASSHO Compaction Test.

Source of Material	Maximum Dry Density (MDD) mm/cc	Optimum Moisture Content (OMC)%
Trail Pit 1	1.94	14.0
Trail Pit 2	1.93	14.2
Trail Pit 3	1.87	14.5
Range	1.87 – 1.94	14.0 - 14.5

According to Oguara (2006) (Table 3) the soil can be classified as a good sub-grade material because of the range of the values. Akpokodje (1986) gave maximum dry density (MDD) and optimum moisture content (OMC) of compaction test for a good backfill material to fall between 1.7- 1.9mg/cc and 7-15% respectively. The MDD and OMC of the soil gotten from the laboratory is used to design the compaction on the road. Hence the compaction on the site should be 100% and above after the In-situ dry density test has been carried out.

A summary of the result obtained from the compaction done during the course of determining the California bearing ratio (CBR) as well as the accepted CBR values for top and bottom is shown in Table 5.

Table 5: The determination of the California bearing ratio (CBR) and accepted CBR values.

Source of Material	Maximum Dry Density (mg/cc)	Optimum Moisture Content %	CBR Value %
Trail Pit 1	1.94	14.0	24
Trail Pit 2	1.93	14.2	16
Trail Pit 3	1.87	14.5	13
Range	1.87 – 1.94	14.0 - 14.5	13 – 24

Specification			> 3

The results of the compaction carried out during the course of determining the C.B.R revealed that the maximum dry density and the optimum moisture content of the soil in each of the mould ranges from 1.87-1.94mg/cc and 14.0-14.5% respectively. The C.B.R ranges from 13-24%.
Generally the result reveals that the soil achieved high density since the range of the MDD falls between 1.7mg/cc-1.9mg/cc and also the C.B.R is greater than 3%which indicates that the soil meets up the standard specification for sub-grade material for road construction according to the Federal Ministry of Works, 1997 and general specification for roads and bridges, British standard code (BS1377:1990).

Table 5: Sieve Analysis.

Source	**% Passing 200**	**ASSHO Classification**
Trail Pit 1	22.5	A – 2 – 7
Trail Pit 2	25.3	A – 2 – 7
Trail Pit 3	25.3	A – 2 – 7
Speciation	< or = 35%	

The result shows that texturally the soils are essentially silty sands and are less than 35%. The soil is been classified as A-2-7, it indicates that the clay content is moderate which implies that it is good for a sub-grade material.

CONCLUSION

The studied samples collected from different trail pits of a burrow pit in Ahoada for geotechnical assessment and suitability of the soil to be used as a sub-grade material in the engineering construction. The ranges of values obtained for liquid limit were 37.0% - 39.7%, 21.3% - 25.2% for plastic limit, and 14.5% 15.9% for the plasticity index. The values for the maximum dry density is 1.87 – 1.94% and for the optimum moisture content is 14.0 – 14.5%. The percentage passing sieve number 200 ranges from 22.5 – 25.5%. The California bearing ratio ranges from 13 - 24% while the value from American Association of Highway Officials (AASHO) classification, classifies the soil as an A-2-7 Sub-grade material. The results indicates that the soil meets the specifications for soil to be used as a sub-grade material with respect to laid down guidelines by the Federal Government of Nigeria. Hence there is no need for the soil to be stabilized.

REFERENCES

Akpokodje, E.G. (1986): The geotechnical properties of lateritic and non lateritic soil Southeastern Nigeria and their evaluation for road construction. Bulletin of International Association of Engineering Geology No. 33, pp 115-3030.

Akpokodje, E.G. (2001): Introduction to engineering Geology, Pp53-233.

Akpokodj, E.G. (2003): The geotechnical Index properties of pavement Soil materials from Aluu, Rivers State.

Allen, J.R. 1965. Quaternary Niger Delta and Adjacent area, sedimentary, sedimentary environments and lithofacies. Bull. A.M. Assoc Petrol. Geol. 49, 543-600.

Amajor L.C (1991): Aquifer in the Benin formation (Miocene-recent) East Niger Delta Nigeria Litho Stratigraphy, Hydraulic and Water quality environment. Geological waters Screven 17 (2) Pp85-101.

American Society for testing and materials ASTM (1969): Procedures for testing soil, committees D-2487 GT Publishing .

Anyanwu, C.M, Adebusuyi, B.S and Kukah T.Y 2003 "Highway maintenance in Nigeria lessons from other countries" Abuja. Research department occasional paper no.27, Central Bank of Nigeria.

British Standard Institute BS1377 (1990): Methods of test of soil for civil engineering purpose Part 2 section 5.

Doust, H. and Omatsola, E. (1990). Niger Delta. In; J.D. Edwards and Santogrossi. (Eds.), Divergent/Passive Margins basin. American Association of Petroleum Geologist Memoir 48. pp. 201-238.

Etu-feotor J.O (1997): Fundamental of petroleum ecology Pp110-130.

Etu-Efeotor, J.O. and Odigi M.I (1983): Water supply Problem in the Eastern Niger Delta Bull.Nigerian Min Geosciences Assoc. 20,183.192.

Federal ministry of Works (1997): General Specification for roads and Bridges Vol. II.

O'flaherty C.A (2001) Soils for road work: In O'flaherty, C.A. (ed). Highways The Location, Design, Construction and Maintenance of Pavements, pp. 133.

Oguara, T.M., 2006. "Highway engineering: pavement design, construction and maintenance" Malt House Press Limited, Lagos, Nigeria.

Okoronkwo, N and Odeyemi, O. (1985): Effects of a Sewage Lagoon Effluent on the Water Quality of the receiving Stream, Environmental Pollution Series, vol. A, No. 37, pp. 71-86.

Ramamurthy, T.N and Sitharam, T.G., 2005. "Geotechnical Engineering" S. Chand and Company Limited, Ram Nagar, New Delhi.

Setraco Nig. Limited manual for Laboratory Analysis.

Short, K.C and Stauble, A.J. (1967): Online of geology of Niger Delta.